

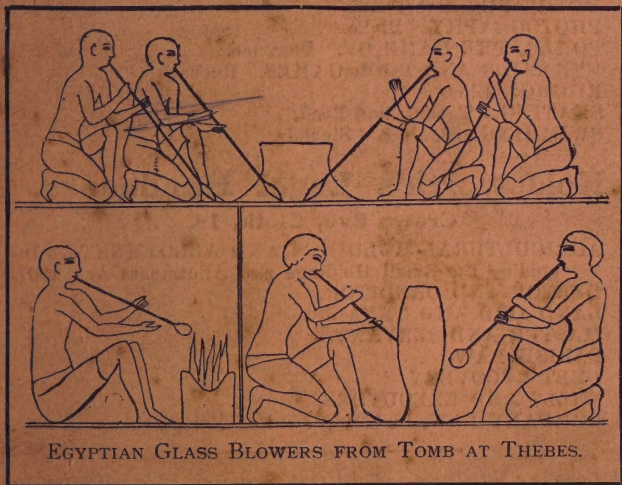
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GLASS-BLOWING

ADAPTED TO LABORATORY WORK

Containing also the Elements
of Decorative Glass-Blowing.

By BERNARD D. BOLAS.



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GLASS-BLOWING

APPLIED TO LABORATORY WORK

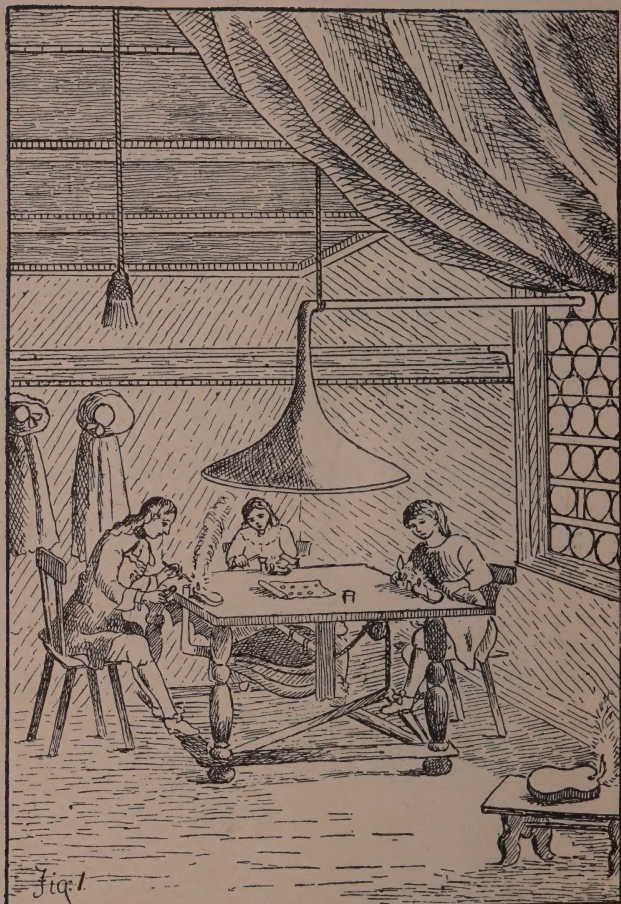


Fig. 1.

Glass Blowers From Kunckeln's *Ars Vitraria Experimentalis*, 1689.

Frontispiece.

No. 12 "The Homeworker's" Series.

GLASS-BLOWING

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CONTAINING ALSO

The Elements of Decorative Glass-Blowing.

BY

BERNARD D. BOLAS.

ILLUSTRATED.

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PREFACE.

THIS concise summary of the technics of Glass-blowing is intended chiefly to give the laboratorian sufficient knowledge of glass-blowing to materially assist him in all ordinary experimental work. The chapter on decorative glass-blowing will, I hope, be sufficient to enable anyone interested to grasp the fundamental principles, and to put him in a position to evolve further means of progress.

Finally I have to acknowledge the matter and illustrations taken from "Glass Blowing and Glass Working," written by my father, T. Bolas, in 1898, and now out of print.

BERNARD D. BOLAS.

London, 1910.

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GLASS-BLOWING.

CHAPTER I.

TOOLS AND APPLIANCES.

Although glass-blowing may be practised with no other appliances than a mouth blowpipe suitably mounted in conjunction with a spirit-lamp, a few pieces of glass tube and a file, there are several appliances that it is important to possess, in order to render glass-blowing of much utility to the student or laboratory worker. The blowpipe and bellows come first in importance as regards apparatus, and upon these the rapidity of the progress made by the student depends to a great extent, therefore each will be considered separately.

The Blowpipe.—Blowpipes may for convenience be divided into two classes; those burning gas, which are usually, but not always, made like the Herapath blowpipe, in which the air jet is surrounded by the flame; and those burning liquid or solid fuel, in which the air is generally blown over the lamp, as in the old-fashioned glass blowers' blowpipe.

Gas Blowpipes are occasionally made in which the air is blown over the flame, but for ordinary

work are better designed on the Herapath principle, as shown in section by (a) Fig. 1, this representing a blowpipe constructed from an $\frac{1}{8}$ -in. gas T, and brass tube.

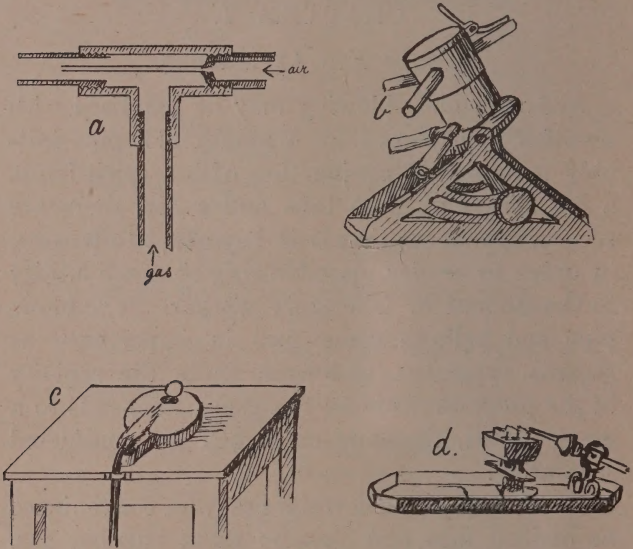


Fig. 1.

The student, if gas is available, will do well to purchase what is known as a "quick change" blowpipe, that is, one in which merely bringing the desired jet into position automatically controls the supply of gas and air; the price of this type of blowpipe is about twenty-five shillings. One made by Letcher is shown by (b), Fig. 1.

A single jet gas blowpipe may be obtained for about four shillings, and both this and the "quick change" blowpipe are obtainable from most dealers in chemical apparatus, or at jewellers' tool shops.

Much of the work mentioned in this book may be done with the simple blowpipe just mentioned, (a), Fig. 1, but for the more delicate decorative and fancy work a "quick change" blowpipe is desirable, although this may be replaced to a great extent by having a second very small blowpipe at hand during work, so that to connect it in place of the other requires only a few seconds.

Blowpipes burning Liquid or Solid Fuel.—Before coal gas came into use, the form of blowpipe, burning oil, shown by (c), Fig. 1, was most usual, but although tolerable for the professional glass-blower, it is unsuitable for occasional work, owing to the fact that if put aside, the oil in the lamp becomes inconveniently thick or viscous.

Perhaps the most suitable fuel, when gas is not available, is ordinary paraffin wax, which is best utilised in the lamp designed by my father, T. Bolas, whose description I give.

"*A Blowpipe Lamp for Tallow, Wax or Oil, (d), Fig. 1.*—This device, originally described and figured in the *Journal of the Society of Arts* (December 2nd, 1898, page 52), consists of a small open tray of iron through which three or more flat tubes pass, and between these tubes flat pieces of woven

wick are placed, the fit being such that the pieces of wick may easily be adjusted for position by means of tweezers.

The flame thus obtained, instead of having one large hollow, is broken or divided by the air that rises through the tubes, so that the combustion is concentrated into a smaller area, and the air blast which is directed across the flame, carries the flame with it in a more complete manner than is the case with the ordinary flame; a more thorough combustion being thus realised.

A chief advantage is the facility with which pieces of wick of varying size may be arranged to suit flames or jets of any size.

Although any fatty fuel may be used, it is specially convenient to use tablets of paraffin wax, obtained by cutting a paraffin candle into three-quarter inch lengths and drawing out the wick, one of these being dropped into the lamp as required."

The Bellows.—If the student is in a position to make financial economy a secondary consideration, I recommend him to buy a table fitted with a circular bellows in the pillar supporting the table top, these tables being made by Enfer, of Paris, but often sold bearing the name of the dealer.

If he is not prepared to buy an Enfer table, the student may obtain a pair of foot bellows such as

are used by jewellers for fusion work and brazing ; a suitable bellows being obtainable in Clerkenwell for ten or twelve shillings.

A tolerable bellows may be made by mounting two ordinary domestic bellows as shown by Fig. 2, a valve being fitted as indicated by the dotted lines, and a piece of metal being fastened on the handle,

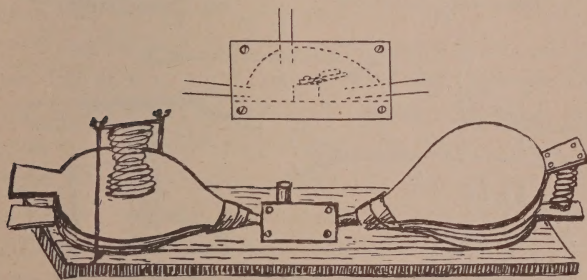


Fig. 2.

so as to take the wear of treading. If desired, a weight may take the place of the spring on the bellows serving as an air chamber.

The Table Top.—This is best made of wood, covered with asbestos millboard, so that warm glass may be laid upon it without the risk of cracking from sudden cooling ; it is also an advantage to have a wooden or metal ledge on each side, to prevent glass tubes or rods from rolling off, and the end nearest the worker should be divided

into inches, by brass, or copper nails, in order to facilitate making a number of articles of the same size.

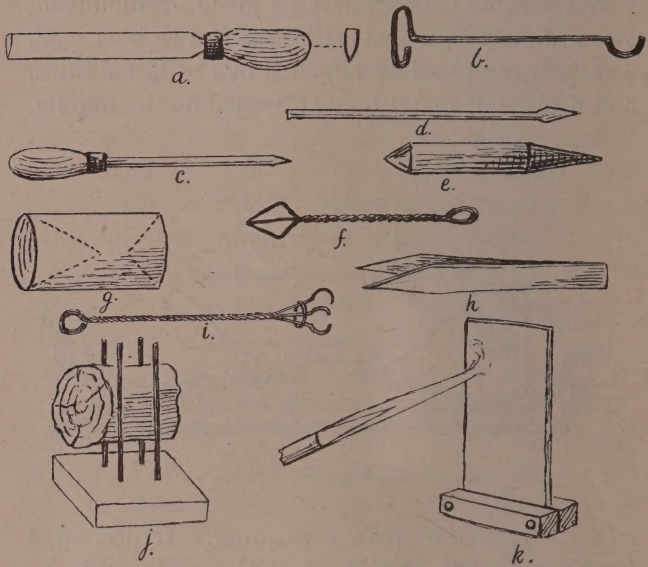


Fig. 3.

Minor Tools and Appliances.—As in many crafts, the beginner may find his progress facilitated by having a large number and varied selection of tools, but as he acquires skill, many of the tools hinder rather than help, therefore, as space is limited, only those tools and appliances of importance will be mentioned, especially as the

ingenious student will readily devise expedients for himself.

The File.—One method of dividing a glass tube is by scratching with a file, and then breaking; but although the correct method is very simple, many use the file in a totally incorrect manner, with the result that the tube is not cut satisfactorily, and that the file is worn out long before it need be.

Correct use of the File in cutting a Tube.—Hold the file in the right hand, take the tube in the left, place the right thumb under the tube and press the edge of the file on the tube over the right thumb; now rotate the top of the tube towards the body, at the same time maintaining sufficient pressure on the file to make a scratched ring round the tube. The tube, if not more than $\frac{3}{8}$ -in. diameter, may now be broken by placing the two thumbs under the rift, and straining the tube until it breaks. If the tube is above $\frac{3}{8}$ -in. diameter, or if it is exceptionally thin-walled, a safer method of breaking is to press a bead of intensely heated glass on the scratch, this will usually cause a crack to follow the scratch round the tube.

CAUTION.—Do not attempt to use the file by using it on the glass as one would a saw, as this merely wears out the file and in addition it seldom cuts the glass properly.

The Glass-blowers' Knife, (a), Fig. 3.—This is an abrading or cutting tool with a very much keener edge than that of a file, and is often useful in place of the file for large or thin-walled tubing.

This tool may well be made of a file about 4 inches long, this being ground as shown in the Figure and mounted in a handle. The knife is used in a similar manner to the file, but the edge should occasionally be sharpened by rubbing on a rough stone, such as a scythe-stone. In grinding the file to make this tool, care should be taken to use abundance of water, in order to prevent the steel becoming softened owing to the heat caused by friction on the grind-stone.

Half Circles for dividing Tubing.—These are often made of iron wire, as shown by (b), Fig. 3, and are intended when heated to redness for use instead of the spot or bead of hot glass for causing a scratch to crack round a tube, as they are more certain in effect. When one of these is used it should approximately correspond in curvature to the outside of the tube on which it is to be used.

Glowing Pastels for leading Cracks.—As the preparation of these is an operation tending to soil both the laboratory and the operator, unless he is accustomed to the work, it is often convenient to prepare a somewhat large number at once, in order to save time and avoid inconvenience. The mode of preparation is as follows:—

Dissolve 60 grains of gum tragacanth in four ounces of water, and to this add 30 grains of gum benzoin, this being first powdered and then dissolved in two drachms of strong alcohol. The tragacanth paste and the spirituous solution of benzoin having been well stirred together, fine charcoal powder is added in such quantity as to form a stiff paste when the whole is well mixed in a mortar. This paste is rolled between boards into sticks about $\frac{1}{4}$ -in. thick and 6-in. long, and these are allowed to dry on a board which has been dusted with charcoal powder in order to prevent adhesion. When dry the pastels are ready for use.

Method of using "Crack Pastels."—If made in accordance with the above formula these pastels will remain glowing when once ignited, and will give sufficient heat for leading a crack in thin glass, but if the glass is thick it is often necessary to maintain a slight current of air from the mouth on the glowing end during work. The glowing pastel should be kept slightly in advance of the crack which will then tend to follow the pastel. The desired path of the crack may with advantage be marked on the glass with Indian ink, and the crack may be commenced by strongly heating an unimportant portion of the glass and allowing a drop of water to fall on the heated part; this will usually cause a large number of cracks to

radiate outwards from the spot, and from these, one tending in approximately the right direction may be selected and led as desired.

Tubes for Cutting Holes in Glass.—Holes from $\frac{1}{4}$ -in. to 1-in. or over in diameter, may be cut or ground in glass by means of a copper tube, or if copper is not available, a brass tube; this should be a trifle smaller than the hole required. The tube may be mounted in a bevel gear drill stock, and used with a thin paste of emery in oil of turpentine. It is almost essential to steady the tube in position on the glass by a piece of cardboard or cork having a hole the size of the outside of the copper tube cut in it, this piece of card being kept in place on the glass by an adhesive, such as Chatterton's compound, or by strips of gummed paper. Sometimes notches or slots are cut in the grinding end, the object of these being to allow a better supply of the grinding material to reach the work. In cutting a hole by this method, care should be taken to lift the copper tube frequently, and care should also be taken to keep the pressure very light at all times, especially when the cutting tube breaks finally through the glass.

Turnpins.—The most generally serviceable form of turnpin consists of an iron rod about $\frac{1}{4}$ -in. thick and 5-ins. long, this being pointed at one end and mounted in a handle, as (c), Fig. 3. The

turnpin is used by holding it still inside the tube to be turned out, and rotating the hot glass against it. This turnpin is sometimes slightly bent in the middle to allow more convenient access to certain work.

Another useful turnpin is made from a metal rod 3 or 4 ins. long and $\frac{1}{8}$ -in. thick, with the end spear-shaped as shown by (d). This being used for turning out small tubes. In this case the turnpin is usually rotated between the thumb and finger, and the glass is held stationary.

Larger turnpins are often made of carbon rod such as is used for electric arcs (e), or of wire (f), Fig. 3.

Outside Turnpin.—When it is necessary to turn in the end of a tube, the outside turnpin may be used. The outside turnpin is often made of carbon with an extinguisher-shaped hollow in the end, see dotted lines in (g), Fig. 3. This turnpin is used by rotating on the outside of the tubes.

Tongs and Tweezers.—A useful form of tweezers is shown by (h), Fig. 3; for occasional work, however, wire tongs, such as (i), Fig. 3, are occasionally used.

Flexible Blowing Tube.—For some work it is convenient to connect a flexible rubber tube to the glass to be expanded and to retain the other end of the flexible tube in the mouth. When

using the blow-tube there is also the advantage of seeing more easily the exact effect of the air pressure.

Tools for Cleaning Glass Tubing.—A rammer or jumper of copper rod about the size of a pencil is often used for driving pieces of rag through the larger size glass tubing; the rag is placed in the tube and the copper rod over it, the tube being now jerked up and down so as to hammer the rag through. Thick copper wire is convenient for pushing rag through tubes, as only copper or similar soft metal should be used inside glass. Iron, cane, or anything having a tendency to scratch, sometimes causes the tube to break after cleaning.

Radiators.—When it is necessary to heat large masses of glass, heat may be conserved by placing a sheet of combed or roughened asbestos in such a position as to reflect the heat back on the glass, thus allowing a larger mass to be heated. For the maximum heat, the radiator may be of charcoal, cut crosswise from a thick stick. For the two forms of radiators, see (*j*) and (*k*), Fig. 3. One disadvantage of the radiator is the impossibility of working with short tubes owing to the radiant heat burning the fingers.

Asbestos Mats.—When hot glass articles have to be laid down, a good form of mat is made of asbestos millboard, of which the surface has been

previously carded or made fluffy with a file card or similar instrument. Mats for some work may be made by glueing asbestos fluff inside a tin tray, or better, on asbestos millboard.

CHAPTER II.

PRELIMINARY EXERCISES:—ADJUSTMENT OF BLOWPIPE, CUTTING, HEATING, DRAWING-OUT, SEALING, TURNING-OUT, BLOWING, BURSTING OR PIERCING, JOINING OR SOLDERING; A RING ON A GLASS TUBE.

On the skill acquired in the above fundamental operations the ultimate success of the worker depends, therefore it is desirable to describe these operations at length. The student who wishes to be successful in glass-blowing must attend with especial care to the work mentioned in this chapter. Before commencing to heat glass adjust the blowpipe as described below.

Adjustment of Gas Blowpipe.—The gas blowpipe should be so adjusted, both by the position of the inner jet and the supply of gas and air, as to give a flame in which the inner blue cone or hollow is distinct from the outer cone of fire; the point of which outer cone is reddish purple in colour when the adjustment is ideal.

Adjustment of Oil Blowpipe.—When the air is blown over the lamp, as is usually the case in a blowpipe burning oil, it is more difficult to judge as to the suitability of the flame for work; or

perhaps it is more correct to say it is difficult to give instructions for judging the flame. If, however the following points are remembered, the adjustment will soon be found easy. The flame is, when the adjustment is good, in most cases less well defined than in the case of the gas, or Herapath blowpipe; it is also more brush-like, is taper with the large end away from the lamp, and the extreme end is often redder.

Making a Test Tube.—We will take as a first exercise a test tube, but instead of hard Bohemian glass such as most test tubes are made of, the work will be easier if flint or soda glass is used. Take a piece of glass tube, flint by preference, about $\frac{1}{2}$ inch in diameter, and $\frac{1}{16}$ or a little under in thickness; with the glass-blower's knife or file make a scratch round the tube (page 13) about 10 inches from the end, taking care not to press too hard and so break the glass. Cause this scratch to crack round the tube by means of hot glass (page 13), and separate the tube. By means of a file remove the sharpness of the ends to avoid cutting the mouth when blowing. Heat the tube gradually by rotating the middle some distance in front of the flame, with both hands, and slowly bring it well into the flame, not so close as to touch the blue cone, however, as the hottest part of the flame is in front of the blue cone, and flint glass if brought too far in, will be

blackened. Continue to rotate the glass in the flame until the tube tends to run together, when this happens draw the two pieces apart, as in *a*, Fig. 4. Take one of the ends between the fingers and again draw off, as shown by *b*, Fig. 4, keeping the point of the flame close to the large tube, in order to leave as little bleb as possible. Re-heat the end and blow gently in order to expand the bleb and to make the end round, and the sealing is finished, unless the bleb was large

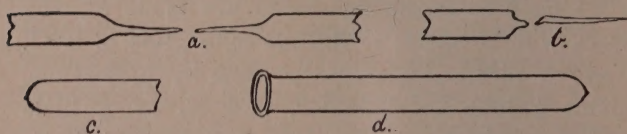


Fig. 4.

and still remains, in which case again re-heat and blow; continuing re-heating and blowing until the sealing looks like that shown by *c*, Fig. 4. Now heat the open end of the tube, turn out by means of a turnpin, and the tube is finished; the finished test tube being shown by (*d*), Fig. 4.

The operation described above, although exceedingly easy when once mastered, may take the student some time to thoroughly understand; he must therefore not be discouraged by a few failures at the commencement.

Blowing Bulbs.—In a few cases, as in making a thermometer, a bulb may be blown on the small tube itself; but in many cases, making a thistle funnel for example, it is well to join a larger and thicker tube to the stem, in order to have sufficient glass to make a strong bulb.

Blowing small Bulb on a tube without additional glass.—If the tube is $\frac{1}{4}$ -in. or under in diameter, the end seals or closes itself automatically on heating, but if much larger than $\frac{1}{4}$ -in. the end is better drawn off and sealed as in making a test tube (c), Fig. 4. When working with a small tube, the tube should be rotated steadily in the flame until sufficient glass has accumulated on the end. The bulb may now be blown in the following manner. Remove the glass from flame, continue to revolve the tube, blow gently into the tube, cease blowing, blow again a little harder, again cease, and again blow; continue this until the bulb is of the desired size. The object of periodic blowing is to allow the thin portions of the bulb to cool slightly during blowing, in order that the bulb may be equal in thickness. The interval between the impulses of blowing may vary from a quarter of a second to two or three seconds, according to the nature of the work, and usually it is convenient not to remove the tube from the mouth between the impulses, but merely to release the pressure by separating the lips. If

at this stage the bulb is not spherical, it may be slightly re-heated so as to soften the glass, but not so as to cause it to collapse in folds, and when soft the bulb may be re-blown.

When blowing glass, care should be taken at all times not to blow suddenly or hard at first, unless it is wished to burst the heated portion.

A Bulb on a large tube.—If the tube on which it is desired to blow a bulb is over $\frac{1}{4}$ -in. in diameter, the end should be sealed before commencing the general heating, and as a rule, the end should not be heated sufficiently to cause it to form a spherical mass; but should only be allowed to thicken, and the bulb blown at that stage.

A large Bulb on a small tube.—When it is desired to blow a large bulb on a small tube, it is as stated above, often convenient to join a piece of larger tube to the small tube, and to blow the bulb from the larger piece. As an exercise involving this and other useful manipulation, the making of a thistle funnel will be described.

Making a Thistle Funnel.—Turn out the end of a small tube as (a), Fig. 5, draw out a piece of larger tube as (b), heat a very small spot on the extremity of the sealed end, and blow smartly into the tube, this should burst out the spot. Now break off the thin blown out glass, so that the thick tube looks like (c), heat both the turned out end of the

small tube and the burst or pierced spot on the larger tube, bring both together and blow slightly to expand the joint as (*d*). Seal the other end of the larger tube as (*e*); heat. Blow to a bulb as (*f*), burst the top of the bulb, break off the thin glass and slightly melt the edges. The thistle funnel should now look like (*g*). If it is desired to give the funnel a more finished appearance the top may be slightly turned out by rotating against the iron wire turnpin mentioned on page 17, in this case the funnel should resemble (*h*), Fig. 5.

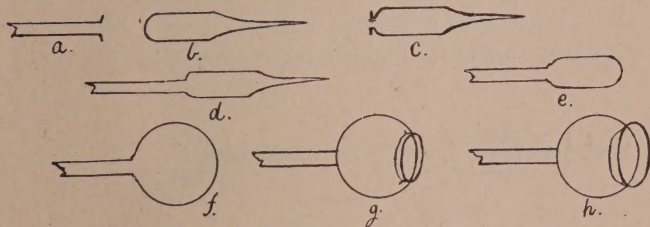


Fig. 5.

Blowing a large Bulb on a small tube without the use of additional glass.—Under some circumstances it is inconvenient to join on a piece of larger glass or thicker tube. When this is the case, sufficient glass to form a satisfactory bulb may generally be obtained by the following method. Heat the tube and blow a bulb on the end. Heat again a little nearer to the open end and again

expand. Repeat this operation. The three bulbs have now to be melted together so as to form a mass of glass suitable for making the final bulb. In order to do this, the first two bulbs should be softened and slightly expanded, then the third bulb is treated in a similar manner. The whole of the expanded portion may now be heated until thoroughly softened all over, and the final bulb is blown.

A Bulb blown from a glass rod.—Occasionally it is desirable to blow a bulb of some foreign glass on a tube, as is the case in making a Daniell's hygrometer. This may be accomplished by fusing a mass of glass on to the end of a rod

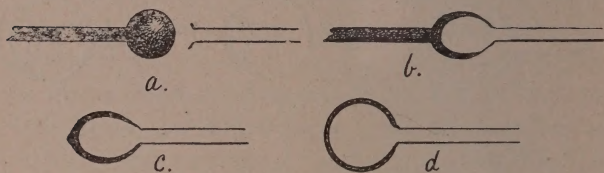


Fig. 6.

of the desired glass as (a), Fig. 6, bringing the hot end of the glass tube against the melted mass; and expanding as (b); drawing off as (c); re-heating and blowing to the finished bulb as shown by (d). For convenience of illustrating, the rod shown is supposed to be of black glass.

Blowing a Bulb on the length of a Tube.—A bulb is sometimes wanted on the length of a tube, as in the old-fashioned dropping pipette. To make a dropping pipette, a large and rather thick walled tube should be heated gradually, drawn out, cut off, and the mouth end turned out, so as to represent (a), Fig. 7. The thick portion should now be rotated in the flame, holding the tube and rotating equally with both hands. When the mass is soft the bulb may be blown, and by slightly separating the hands during blowing, a spherical bulb may be formed. It should be remembered that the rotation must be continued equally during the blowing. The finished pipette is shown by (b), Fig. 7.

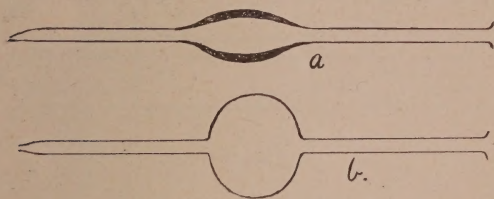


Fig. 7.

Controlling the shape of a Bulb.—The shape of a bulb may be modified by several methods, among which are equal heating, gravitation, and blowing in a mould. In the case of a bulb on the length of a tube, gravitation will be replaced

to some extent by stretching, or compressing the tube during blowing.

Joining Small Tubes.—The most generally applicable method of joining small tubes, end to end, is perhaps the following:—Widen the end of each tube as *a*, Fig. 8. Seal or close the end of one tube. Heat both of the widened ends. Bring lightly into contact, and expand slightly as *b*. Re-soften, and if necessary slightly separate the tubes in order to make the join of the same diameter as the tube. The finished join will often leave a slight trace as *c*, unless very great skill be exercised in finishing, but a trace of the join is usually in no way detrimental to the work.

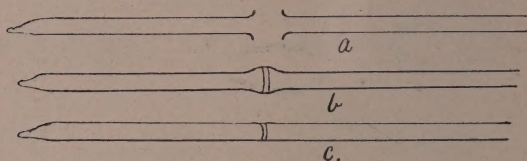


Fig. 8.

Joining Large Tubes.—The method adopted may be similar to that for small tubes, but instead of heating before bringing the two tubes into contact, the turned out ends should be brought together first, then melted by stages; that is to say, commencing the heating at one spot and working round the join, at the same time slightly

pushing the tubes together. The joint should now be expanded, and finished by slight drawing out.

Joining a Large and a Small Tube.—The end of the large tube should be sealed, and a hole is made as described on page 24, under “Making a Thistle Funnel,” and the tubes are then joined as in the case of the two small tubes.

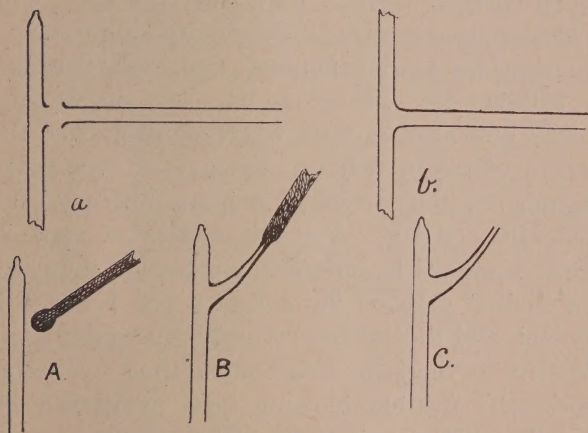


Fig. 9.

Branching.—There are three ordinary methods of branching, each of which is of sufficient importance to warrant a separate description.

Branching by Joining.—To make a branched tube, seal the end of main tube; burst a spot where branch is desired; heat the burst spot to thicken edges; bring branch tube in contact and expand.

If necessary, the joint may be thoroughly re-heated, and by judiciously maintaining slight air pressure, a finished appearance may be given to the work. See (a) and (b) Fig. 9.

Branching by Drawing Out.—When an almost capillary branch is required on the side of a tube, it may be made by strongly heating a spot where the branch is desired, touching this spot with a heated glass or metal rod, and drawing out.

Branching by Blowing from Rod.—This method is suitable for exhaustion branches on vacuum tubes, and also in cases where control over the nature of the branch is necessary, or where the branch is to be formed of a glass differing from that of the article. For this method, a spot on the tube should be softened, a sphere of intensely hot melted glass on the end of a rod brought in contact, and the rod drawn away, maintaining air pressure in the tube at the same time. For this work, the flexible blowing tube mentioned on page 17 is often convenient. The various stages of the operation are shown by A, B and C, Fig. 9.

Joining a Tube to a Bulb.—The simplest method is to burst a spot on the bulb, and to proceed as instructed on page 29, under “Joining a large and a small Tube.” This method, however, is only suitable when the bulb is decidedly thick.

Joining Tube to Bulb (Second method).—In order to make a good join on a thin bulb, it is

often advantageous to locally thicken the bulb before commencing to join the tube. In order to do this, a spot of glass should be fused on the bulb where it is intended to join the tube, then slightly expanded, burst, and the tube joined on as previously explained.

Joining Unlike Glasses.—When joining foreign glasses is unavoidable, the joint should be blown very thin, and, if possible, the joint should be in the substance of a bulb rather than in the course of a tube.

A Welt in the course of a Glass Tube.—If a zone of tube be heated and then the tube is pushed together, a welt will result; this ring, however, requires careful annealing, in order to avoid spontaneous cracking. (See page 41).

CHAPTER III.

VARIOUS OPERATIONS.

Making a Glass Capsule.—A bulb should be blown and when cool divided by the glowing pastel (see page 15). The edges of the capsule may then be finished either by heating or by grinding with emery on a flat stone slab.

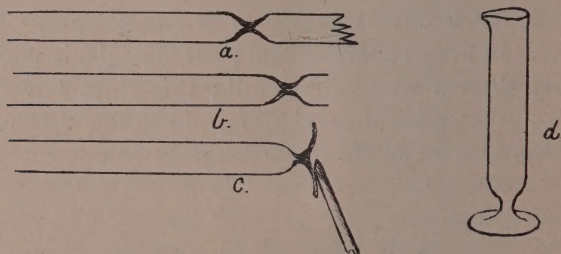


Fig. 10.

A Test Tube with foot.—Contract a tube until the passage is closed, as in (a), Fig. 10. Allow to cool, and by means of the glass-blower's knife (page 14) cut off as shown by (b); heat and expand foot by rotating against a turnpin, as shown by (c). Slightly expand open end of tube, as (d). In making the foot care should be taken not to heat the stem of the foot sufficiently to cause it to soften, or the foot may bend to one side.

Loops, Eyes and Handles.—The various forms of these are sufficiently illustrated by Fig. 11, and excepting (c) the drawings require no further explanation. The handle shown by (c) is made by expanding the top portion from rod, as explained on page 30, under “Branching by blowing from Rod.” The bottom portion is made in a similar manner, and on drawing out the second the two are brought in contact and afterwards fused together.

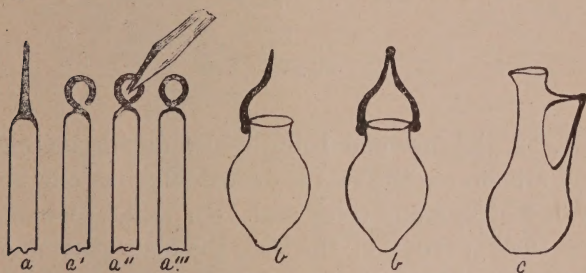


Fig. 11.

Thickened Seal for Pressure.—When a seal has to resist considerable pressure, as in the case of sealed tube operations, a seal made by simply drawing out the end of a tube is usually not sufficiently strong. In such a case the tube should be heated in order to cause the glass to accumulate, and then drawn out slowly. By this means one is enabled to make a seal of any required thickness.

Seal for Water Hammer.—In a case where it is necessary to seal during boiling, as in making a cryophorous, or a water hammer, it is often essential to seal quickly and yet to have a seal that is not exceedingly fragile. This may be accomplished by drawing out the end, as shown by

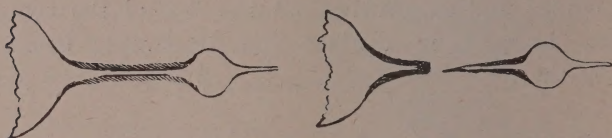


Fig. 12.

Fig. 12, the fine end being sealed during boiling, and afterwards the seal is drawn off, thus one obtains a strong and thick seal. In order to make the thick portion of the seal, the open portion of the tube should be so heated as to allow the glass to gather, then the end should be drawn out (see "Thickened Seal for Pressure," page 33).

Internal Seal for Barometer or Filter Pump.—The internal seal shown by (c^1), Fig. 13, is employed in many pieces of glass apparatus, but only two of the methods of making the seal will be mentioned. In order to make a seal like that shown by (c^1), Fig. 13, a hole should be burst in the tube; the drawn-out tube should be inserted, the joint is fused together, and then expanded by air pressure.

The seal shown by (*d*), Fig. 13, is made by inserting the internal piece in a tube sealed at one end, bursting a spot where the internal piece contacts with the tube; and then joining the small tube

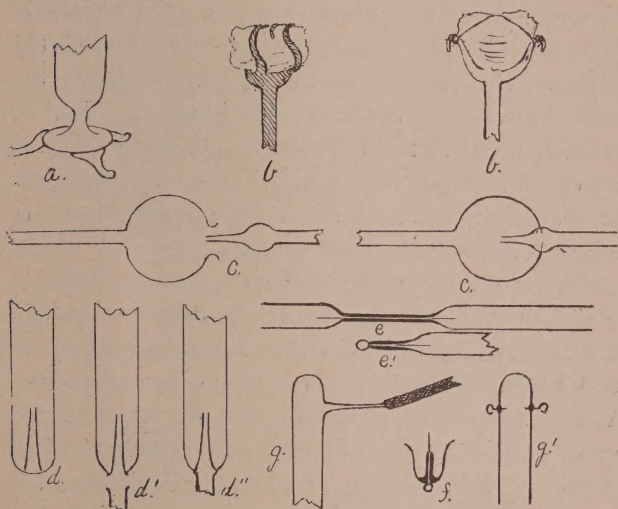


Fig. 13.

to the large, taking care, however, to rotate the work while the glass is soft in order that the internal piece may not tend to become uncentral.

A Foot for Light Articles.—The foot shown by (*a*), Fig. 13, is very suitable for light articles, as it gives a large base and is therefore fairly stable, although the long glass projections are somewhat

liable to damage. The form is illustrated by (a), Fig. 13, but a slight explanation of the illustration is desirable. A small foot should be made as described under "A Test Tube with Foot"; a mass of glass is melted on a rod, and the foot is heated almost to softening point. The mass of glass should now be brought in contact with the edge of the foot so as to cover about $\frac{1}{8}$ of the circumference of the foot; the glass should now be drawn out to the required length and separated by fusion. The other projections being made in a similar manner, and the article being made to stand level, the foot is complete.

Device for Holding Objects in Vacuum Tube.—The foot just mentioned will also serve as a device for holding an object, either for subjecting it to the electric discharge, or for other purposes. When the object is not injured by heating, the glass projections may be bent over it as in (b), Fig. 13, or if heating the object is undesirable, the projections may be made shorter, and bent so as to form hooks, thus enabling the object to be secured in position with wire, as shown by (b¹), Fig. 13.

Bending Tubing.—A blowpipe or Bunsen burner flame is in most cases unsuitable for bending tubing; the flame required being like that of a fish-tail gas burner, this enabling one to heat a considerable length of tube at once, and thereby

to avoid acute bends. When bending thin walled tube it is sometimes advantageous to maintain a slight air pressure in the tube during bending. For such purposes as maintaining air pressure, the flexible rubber tube mentioned on page 17 will often be of service.

Making a Glass Spiral.—When making an object which requires a considerable length of tube to be bent evenly, as a glass spiral for a condenser, it is an advantage to heat several inches of tube at once; for such a purpose I recommend three or four fish-tail burners mounted in a piece of gas barrel 7 or 8 inches long, and adjusted to give the equivalent of one long flame. This device is also useful for bending thin-walled tubing.

Sealing-in Electrodes.—The simplest method of sealing-in an electrode, is to draw the tube out, then insert the platinum wire electrode, and finally to fuse the glass round the wire. This method may also be adopted to seal an electrode in the side of a tube, in which case a tube should be drawn out from a large tube, as explained on page 30, under "Branching by Drawing Out," and the electrode is sealed into this as shown in (*g* and *g*¹), Fig. 13.

Sealing Electrode in exhaustion branch.—Although usual in commercial work, it is by no means essential to have a separate exhaustion branch on a vacuum tube, as exhaustion may take

place through the same tube that the electrode is sealed into. For this purpose the tube is drawn out as (e), Fig. 13, the platinum wire is laid in the contracted tube, and the vacuum tube exhausted through the tube containing the wire. The contracted tube should now be heated so that the external air pressure causes it to contract round the electrode, thus making an air-tight seal. The tube being cut off, and the platinum wire looped; the seal is heated in order to finish it, as shown by (e¹), Fig. 13.

Commercial Electrode work.—In much of the commercial work the electrode, before being sealed in position, is coated with a soft glass often known as enamel, in order to diminish any risk of air entering through the seal; thus giving the electrode an appearance similar to that in (f), Fig. 13. An electrode to be mounted in this manner should be first fused into a glass tube, which will serve as a temporary handle, and then a spiral of enamel is wrapped round the electrode, which is now fused in position and the seal is slightly expanded by air pressure. A special enamel may be obtained for the purpose of joining platinum electrodes to glass, although some difficulty is occasionally experienced in buying small quantities; this, however, is not a serious matter as the simple method of sealing in electrodes, just described is good for almost all laboratory work.

Only platinum has been mentioned in connection with electrode work, as all things being taken in consideration, no other metal is so suitable, and for that reason, the student will do well to adhere to platinum, especially as if he fails in his first attempts at electrode work, he may crush the glass off the platinum wire, and use the same piece again for another attempt.

Thin glass partitions in bulbs.—An easy method of making partitioned bottles or bulbs was demonstrated by T. Bolas, at a meeting of the Royal Photographic Society in the year 1899, and particulars are to be found in the Journal of the Society for May, 1899, page 252. Two, three or more glass tubes being rigidly supported, parallel to each other and the group being heated at one end, air pressure is applied equally in all the tubes. Under these circumstances the bulbs in expanding join together, forming a bottle or bulb with several necks and several divisions.

Reduction of the partitions to the Newtonian "very black" degree of thinness.—At the demonstration mentioned above it was shown that by repeatedly heating a partitioned bulb and by expanding it after each heating, the glass of the partition gradually became absorbed into or incorporated with the main parietes of the bulb, so that the partition could be reduced in thickness until Newton's "very black" stage was reached :

this corresponding (for flint glass) to a thickness of about one three-millionth of an inch.

The partitioned bulb method as a basis for making closed circuits and complex multiple interjoinings.—As a partial illustration of the easy manner in which closed circuits and interjoinings may be made by the partitioned bulb method, the following illustration may be given. Let the commencing point be two straight pieces of small glass tube, held parallel to each other by means of a suitable branch tube or double-blowing tube: two sleeves of india-rubber tubing being used to attach the glass tubes to the blowing tube. The outer and projecting ends being heated and expanded, a partitioned bulb is formed by the side-by-side union of the simultaneously expanding bulbs. After several re-heatings, contractions and expansions, the partition will break down and we shall have a bulb with two parallel necks. If now a branch is joined on at the pole opposite to the two necks, the open ends of the necks may be united by a bulb formed in a similar manner by the union of two simultaneously blown bulbs. In a nearly similar manner it is easy to join a loop circuit to a bulb or other piece of apparatus, or to join the ends of a ring of glass tube, a small temporary branch having been attached for blowing.

Soldering a glass tube to a metal tube.—This may be effected in the most perfect manner by

the method of Cailletet. Platinum or silver is first deposited on the part of the glass tube to be soldered, this being effected by moistening the glass with silver nitrate or platinum tetrachloride and then heating to redness. A layer of copper being now deposited electrolytically on the glass the soldering is done in any usual manner. It is perhaps superfluous to remark that solution must not be put on the hot glass so as to cause fracture. If care is taken and intelligence is exercised, tube joints of this character will be gas tight under high pressures : even 100 or 200 atmospheres.

Annealing.—Glass, when cooled suddenly or unevenly, remains in a permanent condition of strain, and will sometimes crack spontaneously hours, months, or even years after cooling, or in other cases a scratch will cause the article to crack. This condition of strain is prevented by slow and uniform cooling (called annealing) ; this slow cooling ranging from the stage at which the glass is semi-viscous to the ordinary temperature. Some of the properties of unannealed glass may be illustrated by allowing some drops of thoroughly fused glass to fall into a vessel of water, until one remains unbroken ; if the pear-shaped tear of glass be removed from the water it may as a rule be kept intact for any length of time ; but if the tail be broken off, the tear of glass (usually known as a Rupert's drop), will fly to pieces. In pre-

paring Rupert's drops by means of the blowpipe, much patience is often needed, as nearly all crack in the water, or occasionally one may fly violently to pieces immediately on removal from the water. If a piece of unannealed glass, as a Rupert's drop, or a thick piece of imperfectly annealed glass is examined by polarised light, the locality or position of strain will be clearly indicated by coloured lines or patches, or in the case of a thinner piece of glass by dark markings. The student who is able will examine much of his early glass work by polarised light, and thereby study the effects of annealing.

Annealing by a Protective Coating of Carbon.—Many of the articles "blown at the lamp" (*i.e.*, with the blowpipe flame), may be sufficiently annealed by covering with a coating of soot in a smoky flame, and then being slowly raised above the flame so as to gradually diminish the heat until the article is cool. Thin and uniform articles, as bulbs, usually require no annealing, the only precautions necessary being to avoid allowing them to cool in contact with a conducting material, and also to avoid allowing them to cool in a draught.

Points to be observed in Annealing.—To summarise:—The object of annealing is chiefly to avoid risk of spontaneous cracking. Annealing is accomplished by cooling slowly and evenly from

the softening point of the glass to normal temperature. Badly annealed work may often be detected by examination in polarised light. Thick or uneven articles require more careful annealing than thin or even articles.

CHAPTER IV:

DECORATIVE AND FANCY WORK, BLOWN LIMBS,
THE BLOWPIPE FLAME AS A MODELLING
TOOL, SPIRAL OF COLOURED GLASS ON
TUBE, SPIRAL ON BULB, USE OF POW-
DERED GLASS OR ENAMEL, SCRAP GLASS
IN DECORATIVE WORK, GLASS-BLOWING
WITH SIMPLE APPARATUS.

Most fascinating decorative work may be done in glass or enamel by means of the blowpipe, provided that the artist is sufficiently skilled in manipulation to control his material, not to be controlled by it. Until this power is acquired, the result of an attempt at decorative work will almost certainly be a failure, but the student must be fully prepared to patiently overcome such difficulties as he is almost certain to meet with, and further he should remember that a simple article made well is far better in appearance than a complex article showing signs of careless or unskilled workmanship. In order to give the student some idea of those fancy articles coming within the scope of blown glass, the illustrations in Fig. 14 are given, most of these being described at length in the subsequent parts of this chapter.

These illustrations must not, however, be taken as in any way setting a limit on the applicability of the blowpipe to decorative work, as new methods, designs or modifications are continually occurring to the intelligent worker.

Blown Limbs.—The limbs of a figure, such as the Cartesian diver, (*a* and *a'*) Fig. 14, are usually made in a manner similar to that explained on

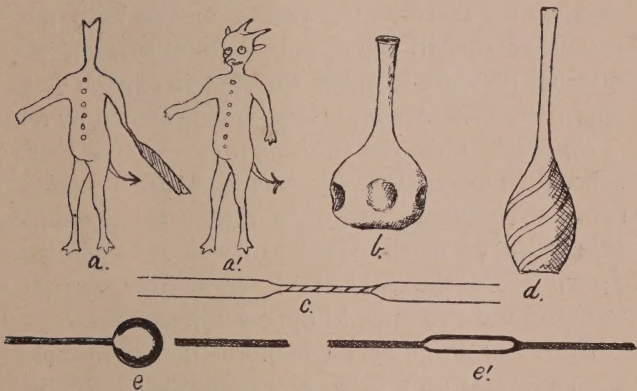


Fig. 14.

page 30, under "Branching by Blowing from Rod," and are bent while being drawn out. The body of the figure simply consists of a double bulb, and the head is made on the stem of the bulb forming the body, the air for expanding the head being supplied through the hollow tail, this

being afterwards closed and the barb added. The features are spots of black glass fused on and slightly expanded, and the horns are made by a method similar to that used for the limbs.

The Blowpipe Flame as a Modelling Tool.—A small pointed flame in conjunction with the flexible air-tube mentioned on page 17, will give a most surprising power of modifying or altering the shape of a bulb. The method of using consists simply in softening a spot on the bulb, and by either slightly increasing or diminishing the internal pressure to cause the spot to expand or to sink inwards. A simple specimen is shown by (b).

Spiral of Coloured Glass on tube.—A spiral on a tube, such as (c), Fig. 14, may be made by fusing spots of coloured glass on a rather thick walled tube, then when the spots are well incorporated, drawing out the tube, and while drawing out, twisting the two ends in opposite directions.

Spiral on Bulb.—This is more difficult to make than a spiral on a tube, but a spiraled bulb like (d), Fig. 14, may be made as follows: Draw out a piece of rather thick-walled tube, fuse on the spots of coloured glass, soften the thick portion as described under “Blowing a Bulb on a length of Tube,” and expand as described there, except that during blowing the two hands should rotate the glass in opposite directions, so as to give the spiral effect. One of the tubes should now be sealed off,

the bulb re-heated, the bottom flattened, and the top of the neck turned out; thus giving the finished article as shown.

Use of Powdered Glass or Enamel.—In decorative work, remarkable colour effects may be obtained by rolling the soft glass in powdered coloured glass or enamel before blowing.

CHAPTER V

CHOICE OF GLASS, VARIOUS GLASSES, ENAMELS, ORDERING AND SELECTING TUBE, CLEANING.

Silica as a Glass.—Silica when fused forms a wonderfully hard and unalterable glass; this glass being of special use for chemical apparatus intended to stand a high temperature, and to be capable of resisting extremely sudden changes of temperature without cracking. Some remarkably useful silica apparatus is now on the market. A silica test tube heated to redness and plunged into cold water will remain uncracked. The high melting point of silica, however, places it outside the use of the ordinary glass-worker. The three glasses of prime importance to the laboratory worker are: Hard Bohemian or combustion glass, as it is often called, Flint or lead glass, and Soda glass. Soft enamel is occasionally useful, but this is used more in decorative work.

Combustion Glass.—Consists of silica, potash, and lime, these making a hard and difficultly fusible glass, which when heated becomes viscous rather than suddenly fluid as is the case with soft enamels. Owing to its infusibility, combustion glass is well suited for chemical apparatus in-

tended to be subjected to high temperatures. Owing to the high melting point of combustion glass and the resultant difficulty of working, it is less used than ordinary flint or soda glass.

Flint or Lead Glass.—This glass takes its name from the old practice of using calcined, quenched, and pulverised flint, as the silicious base of the finer glass. A formula such as the old glass being:—

Silica (as above)	...	...	100	parts
Red Lead	...	...	80	„
Carbonate of Potassium	...	...	35	„
Nitre	...	...	3	„

To this was often added a little manganese dioxide, in order to oxidise any traces of iron to the ferric state, avoiding a greenish or brown tint. Although lead-glass is blackened when held in the reducing part of the flame, it is in all things considered the most suitable glass for general laboratory use, as it requires less annealing and is less liable to crack spontaneously than either soda glass or soft enamel.

Soda Glass.—Is not blackened in any portion of the flame and is therefore easier for the novice to work, but it tends more to crack on heating, and is also less reliable than flint glass both as regards keeping qualities and devitrification.

Devitrification.—Most kinds of glass, if long exposed to heat at the softening point, become crystalline or fibrous, rough on the surface, and at

the same time very hard and less fusible. Glass thus changed is called Reaumur's porcelain, and decorative articles are sometimes converted into it. Scraps or crushings of suitable glass placed in a mould and baked at the softening temperature will agglomerate and devitrify, giving tiles almost as hard as granite. Glass which has been devitrified can be again vitrified by exposure to a considerably higher temperature than its original meeting point; hence is it that, when glass having only a slight tendency to devitrify is worked at the blow-pipe, the rough surface, characteristic of devitrified glass, is only observable at the margins of these parts which have been intensely heated. To discuss those chemical conditions which favour and disfavour devitrification would be beyond the scope of the present work, but it may be mentioned that flint glass is so little subject to devitrification that it is rare to find a sample of tubing which shows trace of this action even in the most prolonged blowpipe operations.

Making Small Rods and Tubes.—When preparing special glasses it is often necessary to draw the material into rods or tubes. This may be done by first fusing together the ingredients of the glass, either in a crucible, or for small quantities, on a slab of fire-clay; the glass should be allowed to harden and then be broken to pieces, these pieces being now melted together on the end of a

clay pipe-stem, and drawn into rod with the assistance of a second pipe-stem. If it is desired to draw into tube the mass should be blown into a bulb before drawing, and in some cases a slight air pressure should be maintained during the operation of drawing. In this manner, fragments of a broken bottle may be made into rods or tubing. Drawing a tube with the aid of two pipe-stems is shown by (*e* and *e*¹), Fig. 14.

Ordering and Selecting Tube.—When possible, it is well to go to the dealer and select tube from his stock; if this is not practicable the approximate inside and outside measurements of the tube required should be given. Glass tube is generally sold by weight, the price for colourless being from about eight pence to a shilling a pound for small quantities. When buying tube from a miscellaneous stock, it is often well to purchase a small quantity as a sample before buying a larger quantity. Tubes should be stored in a place free from dust, as the trouble of cleaning the inside of a tube is often considerable.

Cleaning Tube.—Glass tube may be cleaned by driving a piece of moist rag through, by means of a copper jumper, as described on page 18, or the rag may be pushed through with a stout copper wire. Iron or Bamboo should never be used to push the rag through, as these tend to scratch the inside, and the slightest scratch inside a tube will

often cause it to break, either spontaneously or on heating. The tube should not be used until the inside is dry, as water may run back on the hot portion and cause a fracture, therefore the tubes should be cleaned some time before being required, and left in a vertical position to drain and dry. A tube may be dried by first absorbing as much water as possible by passing soft dry rag through, warming the whole tube, and passing a current of air from the bellows through the tube until dry; or if a bellows is not available by warming the tube, blowing air through with the mouth, and finally removing the last traces of moist air by *sucking* air through until dry.

CHAPTER VI.

GLASS-BLOWING WITH SIMPLE OR EXTEMPORANEOUS APPARATUS.

As mentioned in the first chapter, glass-blowing may be practised with few simple appliances, and although the resultant work may be small, a considerable insight into the principles of glass-blowing may be obtained. The simplest useful form of blowpipe for glass-blowing is a mouth blowpipe, such as is used by electricians or jewellers, this being firmly fixed to a board or other foot, and adjusted, so as to blow air through a spirit, oil, or candle flame. When this is used, the air may be supplied from the mouth, the cheeks being used as an air reservoir, thus allowing a current of air to be maintained. As this requires considerable practice, a better form of mouth blowpipe is one in which the air is blown from the mouth into an elastic reservoir and passes from thence through the blowpipe jet. When the reservoir is used, a valve should be placed between the mouth and the reservoir, this valve being arranged to prevent return of air from the reservoir to the mouth. The jet for this blowpipe may well be a piece of drawn out glass tube

mounted so as to project just into a flame either of gas or oil. Although this form of blowpipe is cheap and simple to construct, moderately large work may be done with it, such as making test tubes, up to 1 or even $1\frac{1}{2}$ inches in diameter.

A very serious disadvantage of this form of blowpipe, when used regularly, is that the air reservoir becomes foul and wet from the condensed moisture of the breath, but in spite of this disadvantage, such a blowpipe often proves exceedingly useful in cases of emergency.

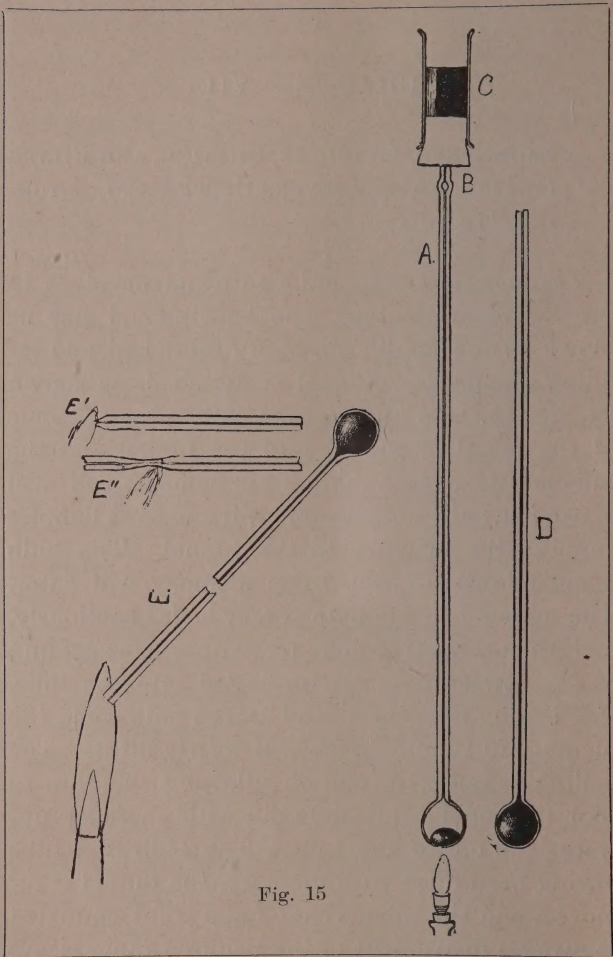
The rubber hand blowers sold for spray bottles and other purposes are capable of supplying air to a small blowpipe, but as they deliver air at rather high pressure, the air supply should be regulated either by a stopcock, or by pinching the tube, the elastic wind chamber being maintained full of air during work. This form of blower being somewhat unsuitable for treading with the foot, involves the use of one hand. Working it under the arm also seriously interferes with glass-blowing.

Small quantities of coloured tube or rod may be made by melting fragments of bottle glass, beads, or scraps of window glass, these are then drawn into tube or rod as explained on page 50.

CHAPTER VII.

THERMOMETERS, GRINDING, CUTTING, AND FILING GLASS, GLASS VALVES, STOPPERING, ETCH- ING, GRADUATION.

Thermometers.—In order to avoid moisture in the thermometer tube, the bulb should not be blown by the mouth, but by a rubber ball, and for filling a temporary funnel is attached, as shown by Fig. 15. To fill the tube with mercury, some of the metal is poured into the funnel and the tube is held over a minute gas flame, which will expand the air, so that some will escape as bubbles through the mercury to the funnel. The bulb being allowed to cool, some mercury will enter. The mercury in the bulb is now boiled cautiously, and when threads of mercury, with a short column of air between each, are projected into the tube, the boiling is stopped, and as the bulb cools the mercury in running back will nearly fill it. The boiling is renewed, and on allowing the bulb to cool it should completely fill with mercury upwards and out of the tube. The bulb and tube having been filled with mercury, the funnel is removed, and the tube is cut off at a point estimated to give an instrument of the required range, leav-



ing the thermometer, as shown at D. Heat is now applied to the bulb, so as to raise it to a temperature a trifle over that which the instrument is to indicate, and this causes some of the mercury to flow out. While the tube is full of the expanded mercury, or just as the mercury has drawn back for about $\frac{1}{32}$ of an inch, a small blowpipe flame is directed against the cut end, as shown by E, Fig. 15, when the end will soften and close, leaving a partial vacuum as the thread of mercury draws back. Before sealing, the tube may be drawn to an open point as shown by E'; or it may be drawn out as shown by E''. The enclosed thermometer, Fig. 16, is largely used for dairy and other work, where easy cleaning is a consideration. The bulb is almost invariably blown from the material of the outer tube, and the fine tube is sealed in by a method which is substantially similar to the method for sealing in a piece for an air-trap (page 35). The stages are as follows:—Fig. 16, B, shows the fine inner tube spread out by blowing a bulb and opening it, as in making a thistle funnel, (page 24), only in this case the bulb is turned out much more. C shows the inner tube placed in the outer tube; this latter being drawn out as shown. Heat is applied at the bottom until the two pieces have thoroughly united, and by blowing into the piece as a whole, the lower part is expanded into a bulb.

Fig. 16

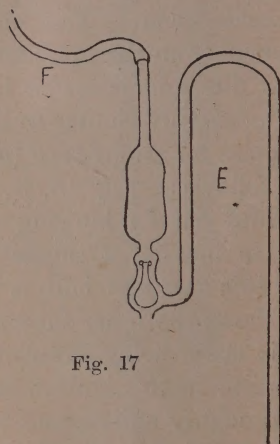
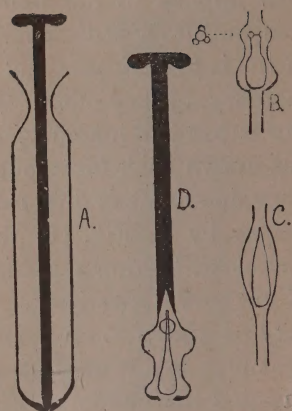
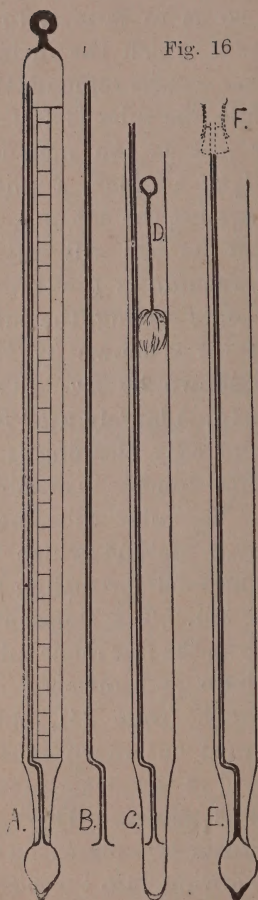


Fig. 17

The filling offers no difficulty. For sealing the inner tube, pinch off the inner tube at the required depth, by a pair of hard parallel jawed cutting nippers, bring up the mercury and seal the end by a small flame. The insertion of the scale, whether on paper or other material, requires a special remark.

Valves, a Valve Syphon, and a Valve Acid Lifter.

—A ground-in valve, made like the stopper of a bottle, but rather more conical, acts fairly well if well covered with a lubricant such as vaseline, but if not so lubricated it is almost sure to jam and fix: this, however, is not the case if one can raise the valve by hand power, as in the acid lifter shown by A, Fig. 17. I have sometimes succeeded in making very tight valves in light glass apparatus without grinding, and, moreover, valves which lift with very little pressure, and do not stick. Such a valve is shown by B, Fig. 17. The spindle is a melted drop on a slightly drawn out stem, and on the top of it three little drops of glass are melted, which prevent the closing of the upper tube when the valve lifts. E, Fig. 17, shows a valved syphon.

Filing and Grinding Glass.—If a common file is kept thoroughly wet with oil of turpentine, in which camphor has been dissolved to saturation, the softer kinds of glass may be filed almost as easily as brass is ordinarily filed. A saw with a plain copper

blade may be used with a paste of emery and paraffin oil. An old American "star" hack saw, the teeth of which have been singly crushed off by sharp blows with a hammer, the tooth being laid on the edge of a steel stake, makes a useful tool for sawing glass if kept well wetted with the solution of camphor in turpentine.

Drilling Small Holes.—If a steel drill, made to a rather long spear-like point and hardened to the extreme, is used with the above-mentioned solution of camphor in oil of turpentine, very quick progress can be made, but a broken end of hard steel will serve when once a beginning has been made.

Grinding Stoppers.—In almost all cases when the glass-blower wishes to stopper any vessel, the mouth is swelled out by a turnpin, and the piece to form the stopper is drawn to something like a corresponding slope. The stopper and its seating may be separately ground, with metal cones of suitable angle, and they are afterwards ground together with a mixture of emery and paraffin oil.

Stopcocks.—These are frequently made in a considerable thickening on a piece of tube, the hole for the plug being first cut out, and then ground out conical with the stoppering tool just mentioned. The cross head of the plug can be made by melting up a spheroid and flattening it, and the grinding of the plug in position is merely

an operation of stoppering, as already described. The small hole across the plug must be drilled.

Etching and Graduating Glass.—After graduations, scales, lines or designs have been made through a wax ground the work should be carefully examined for such defects as are easily remedied at this stage, a false line being readily melted over by a hot wire. Bare places likely to be affected by the etching material should be brushed over with melted wax softened by a little oil of turpentine. The vapour hydrofluoric acid has hitherto been generally preferred, because it gives duller lines than the liquid hydrofluoric acid, but a suitable mixture of hydrochloric acid, fluoride of sodium, and an inert powder such as sulphate of barium, will give a far better dull line etching than the vapour, and it is more uniform in its action and more convenient in many respects.

A satisfactory etching mixture is :—

Strong hydrochloric acid ... 1 fluid ounce

Precipitated sulphate of barium 120 grains

Fluoride of sodium 120 grains

This should be brushed well in, left until the object is sufficiently etched (usually about ten minutes), and then washed off.

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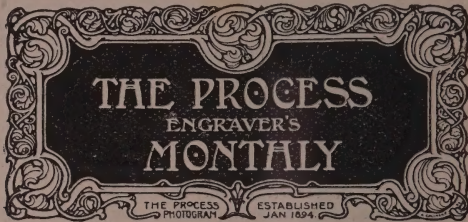
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